A Study of SSVEP Responses in Case of Overt and Covert Visual Attention with Different View Angles

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***Abstract*— Standard automated perimetry is a common visual field test in clinical practices. But the test effectiveness relies on responses from subject and technician experience in operating the test equipment. Therefore, it calls for a more objective way of measuring visual field; as such we consider SSVEP as potential suitable technique. SSVEP is extensively studied in the context of a brain-computer interface, where successful SSVEP detection relies on fovea vision. But peripheral vision is more critical in assessing the effective field of view in Glaucoma patients. So this study investigates how SSVEP responses exhibit with different view angles and subject's visual attention in peripheral vision. We designed an experiment with single flickering stimulus at three view angles horizontally. Subject performed overt, covert and no visual attention at each stimulus position, while EEG and eye tracking data are recorded simultaneously. We used spectral power amplitude ratio and maximum canonical correlation coefficients to evaluate SSVEP responses. According to 1-way and 2-way ANOVA tests, there is no statistical significant difference among SSVEP responses when subject paid overt or covert visual attention, as well as with different view angles. But SSVEP responses among stimulus frequencies are statistically significant ($p<0.001$). This might suggest that SSVEP can be a usable approach to measure visual fields when subject oriented with covert visual attention. So reliable SSVEP responses highly depend on the choice of stimulus frequency but do not depend significantly on different visual attention and view angles.**

Keywords*— *Visual field test, SSVEP responses, Peripheral vision, Field of view, Visual attention, View angles

I. INTRODUCTION

As Electroencephalography (EEG) offers good temporal resolution with low-cost and high usability, Brain-Computer Interface (BCI) based on EEG can be seen in numerous applications [1]. Among EEG modality, Steady-State Visual Evoked Potential (SSVEP) is highly popular for visual speller due to high throughputs, less requirement on user training and high amplitude response [2]. But reliable SSVEP responses detection relies on fovea vision while subject fixates gazes constantly and pays overt attention at the target flickering stimulus. Such direct gaze dependency with overt attention using fovea vision to target stimulus limits SSVEP applicability in real-world usage. The various types of VEP are also used for visual field assessment along with standard clinical functional tests [3, 5]. Currently, standard automated perimetry is a common visual field test used in clinical practices [4, 5]. But the test effectiveness relies on subjective responses with respect to stimulus seen or not on the screen, and skills of technicians in operating the test equipment. Therefore, a technological solution that provides objective assessment and ease of accessibility is highly desirable to improve visual field test efficacy. SSVEP shows potentials in vision assessment due to its objective responses and meaning to stimulus frequencies [3, 5]. The challenging issue is that user's gaze behaviors and attention states highly influence the test performance in both clinical standard and SSVEP-based visual field assessment [3, 5]. So it is important to understand and characterise SSVEP responses among different visual attentions, view angles and stimulus frequencies; for objective interpretation of evoked responses.

The symptoms for vision loss in Glaucoma patients can be due to multiple factors besides peripheral vision loss [4]. For successful diagnosis, Glaucoma patients are required to assess their visual field as early and regularly as possible, as majority of them can suffer silently from peripheral vision loss [5]. Assessment of vision loss are usually complex and existing standard tests have limited capability in detecting the disease at early states [4]. The study with mobile BCI and Virtual Reality shows high correlation between SSVEP measurements and standard visual field test [5]. Another study with testing on fovea and peripheral defects reveals no change or slight increase in SSVEP response power with varying view angles in peripheral field [6]. That study concludes that, SSVEP can provide objective indicator in testing visual acuity and contrast sensitivity with paediatric subjects.

Although peripheral vision is vulnerable to clutter, it covers 99.9% of visual field and responsible for many visual tasks [7]. There is still limited understanding on neural mechanism of peripheral vision especially how it can be useful and optimized for SSVEP tasks. Some studies evaluated on SSVEP difference between visual attentions resulted the mixed and contradicting outcomes [8, 9, 10]. So we aim to further investigate on how visual attention affects SSVEP responses in both fovea and peripheral vision. This study focuses on studying the influence of view angles, visual attentions, frequencies in modulating SSVEP responses and characteristics in peripheral vision [11]. This might also be applicable to design gaze independent SSVEP solution to detect desired target with reliable SSVEP responses without reliance on direct gaze and overt attention [12]. Our study is motivated by [13] that suggests attention might be in broader visual field that can share between separated regions over extended duration. This imply SSVEP responses by flickering stimulus within attentional spotlight cannot be ignored regardless of subject's attention state and view angle.

The relationship between SSVEP responses with visual attention [8, 9] and view angles [6] separately were well studied. But none of them consider how combined visual attentions and view angles with single flickering stimulus affect SSVEP responses. So this study differs with previous studies [6, 8, 9] by evaluating how SSVEP response changes across effective Field of View (FoV) range in three parameters: view angles, visual attention states and stimulus frequency. In order to eliminate visual competition and clutter influence on SSVEP response, our experiment design includes single flickering stimulus positioned at seven different places according to varying view angles. Our goal is to quantify the relationship between SSVEP responses and FoV under specific attention and view angles leading towards peripheral FoV assessment. To enhance data reliability, our experiment records EEG and eye tracker simultaneously ensuring EEG responses with correct spatial visual attention at different view angles.

The rest of the paper is organized in four sections. Section II discusses the research hypotheses, experiment design, data collection setup and experiment tasks scenario. Section III outlines the analysis approach, methods used and derivation of evaluation measures. Section IV explains the results achieved with selected evaluation criteria by applying statistical analysis. Section V discusses the highlights of the results with potential limitations, future extension and conclusion from the study.

II. Experiment Design and Hypotheses

From speller, neuro-feedback to neuroscience studies using SSVEP BCI, stimulus design is unique according to specific requirements and goals set in the studies [2, 3, 5, 6]. Similar to visual field test scenario [5], we design user interface with single flickering stimulus to evaluate SSVEP responses in useful FoV with two evaluation criteria. Our initial hypothesis is that similar SSVEP responses can be obtained among different view angles and visual attention. Additionally, we tested how difference in stimulus frequencies affects SSVEP responses in current setup. The simultaneous EEG and eye tracker recordings ensure selection of representative EEG data on specific attention conditions. As our experiment uses single stimulus in evaluating SSVEP responses with different visual attention and view angles, our work differs from other experiments [8, 9, 10] in eliminating effects of visual rivalry and competitive neural mechanism at visual cortex [3, 7].

A. Experiment Design and Setup

We design an experiment similar to scenario of visual field test where subject requires looking at center of the screen while flickering light displayed across the screen at different view angles. Instead of multiple stimuli flickering simultaneously [2, 5], we use single flickering stimuli presented on computer screen with view angles varied from 0 to 30 degrees with specific stimulus frequency per session in contrast to [10, 14]. Instead of multifocal or matrix-like stimulus design [2, 5, 6], all stimuli located horizontally at specific view angle, labelled C_0 at center (0 degree) and L_i and R_i (i=1, 2, 3) for left and right sides of center crosshair that is overlapped with C_0 respectively according to three view angles (10, 20 and 30 degrees) as shown in Fig. 1(a).

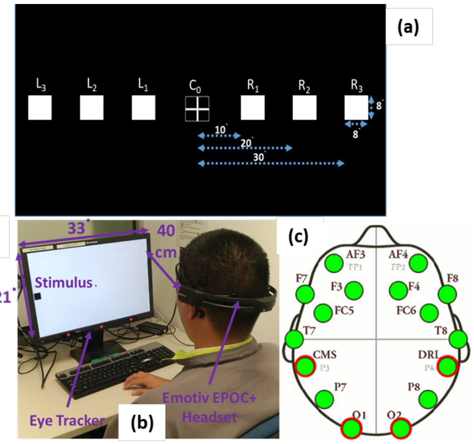

Fig. 1. Experiment design and setup (a) Stimulus Layout (b) Hardware setup with Subject (c) Electrodes used in experiment (highlighted in red color)

A desktop remote eye tracker (Tobii Inc.) was attached at monitor screen as shown in Fig 3(b). We use consumer EEG headset (EPOC+, Emotiv Inc.) with only using 4 electrodes as shown in Fig 3(c) by sampling data at 128 Hz. The reason to only select O_1 and O_2 electrodes is that the previous study identified similar SSVEP amplitudes for fovea and peripheral vision at O_1 and O_2 [6]. After all hardware setup, subject sits in front of monitor (22" wide screen LCD) with 40 cm distance resulting viewing angle subtended to 33' horizontal and 21' vertical as shown Fig 3(b). Eye tracker is calibrated per subject for accurate eye gazes tracking before each experiment. Both EEG and eye tracking data are simultaneously recorded with precise event timing for segmenting specific stimulus events according to experiment sequence and tasks specified in Fig. 2.

B. Experiment Scenario

We use four stimulus frequencies (8.57, 10, 12, 15 Hz) as these flickering rates can be directly derived by dividing screen refresh rate (60Hz refresh rate monitor for stimulus display) with number of frames. Also, the stimulus flickering rate with 8-15Hz range modulates reliable and high amplitude SSVEP responses [16]. For each frequency, subject will attend to each stimulus in three visual attention conditions: 'overt' where gaze and attention directed at target stimulus, 'covert' where gaze is at center crosshair where attention will be on target stimulus and 'no' where gaze and attention are at center crosshair regardless of the target [11, 12]. Each stimulus is repeated for four trials at random position for all attention conditions according to experiment design in Fig 2(a). Duration of each stimulus is 10 seconds for three tasks as shown in Fig 2(b): 'cue' showing the position of the target (1 sec), 'stimulus' flickering in onset-offset pattern (5 sec) and 'rest' blank screen with crosshair for subject to take a short rest (4 sec). Except stimulus C_0 that always starts in each trial, the side stimuli flicker at random positions with alternate left and right (L_i followed by R_i). Subject can take additional rest if desired (no specific timing at 'B' in Fig 2(a)) to ensure that subject does not suffer from high visual fatigue during experiment that might affect SSVEP responses [2].

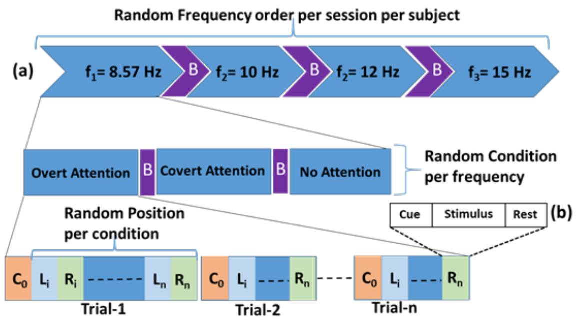

Fig. 2. Experiment Scenario (a) Sequence of activities with different frequency, attention conditions and stimulus position (b) Tasks per stimulus

III. Analnysis And Methodology

With synchronized EEG and eye tracker recording from three subjects, we segment both data from each experiment session according to experiment activities to obtain data segments of each stimulus flickering at specific view angle, attention and frequency. After segmenting the data, validation of correct visual attention according to experiment task was performed manually using eye gazes. We discard EEG segments if respective eye gaze coordinates are deviated in each attention state as well as EEG segments with high ocular artifacts using eye position data. Fig. 3 shows correct gaze positions obtained for left-most stimulus with 30 degrees view angle (L_3) in covert, no and overt attention in 'top left', 'top right' and 'bottom left' graph respectively. The gaze positions at center C_0 'bottom right' represent conditions during 'rest' or overt attention at center stimulus.

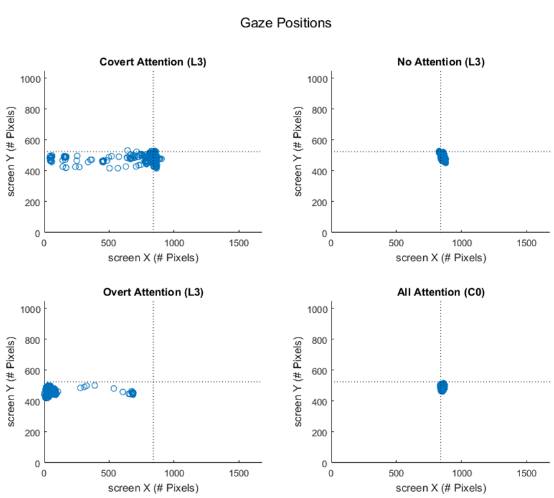

Fig. 3. Eye Gaze positions (X and Y coordinates) at L_3 stimulus position with different subject's attention states and C_0 position

There is similarity in gaze positions between no attention (any L_i and R_i position) and center position as can be seen (two right side graphs). In our experiment, around 20% sessions of recorded EEG data are discarded due to unstable or incorrect gaze positions and excessive ocular artifacts. By including above processes with the rest of analysis and methodologies applied in our study can be found in Fig. 4.

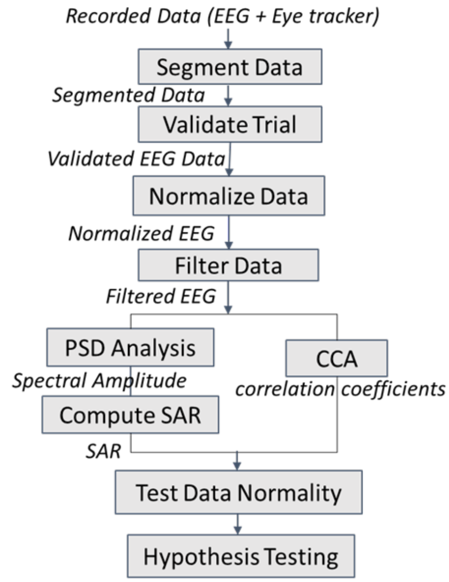

Fig. 4. Overview of data analysis and metdhologies applied in evaluation

To evaluate SSVEP responses in both fovea and peripheral vision (different view angles and visual attention), we derive the spectral amplitude ratio (SAR) from power spectral features [17] and, canonical correlation coefficients (CCC) [2] by applying multivariate analysis. These criteria can be quantified how strong is evoked responses over background noise with respect to the stimulus frequency. From eye gaze verified EEG segments, fourth order Butterworth band pass filter (4 to 40 Hz passband) after 50Hz notch filter were applied at each segment after normalizing raw EEG signals. To compute SAR, Power Spectral Density (PSD) analysis was performed using Welch's method on 4 sec EEG data by discarding 0.5 sec data (64 samples) from start and end of the segment. To prevent spectral leakage, we used Hanning window of 512 points size with 50% overlapped in extracting PSD features with frequency resolution of 0.25 Hz (Δf).

$$SAR = \frac{|Y_S|}{\sum_{i=5}^{35} |Y_i| - |Y_S|}, where |Y_S| = \sum_{k=1}^{2} \Phi_k \pm 2\Delta f \quad (1)$$

As shown in Eq (1), SAR is computed by dividing the amplitude power of desired SSVEP responses, $|Y_S|$ (at fundamental frequency (k=1) and second harmonic (k=2) of stimulus frequency) with the mean amplitude power of the background noises, $|Y_i|$ from 5 to 35 Hz range excluding $|Y_S|$. SAR is a direct indicator of how strong the desired stimulus amplitude (with harmonics) is presented in spectral response compared with undesirable frequency's amplitudes in specific frequency range. We use SAR to examine whether there is difference in spectral response fidelity among view angles and visual attentions without any signal enhancement. We further examine whether there is any combined influence of those experiment parameters to SSVEP responses in term of SAR.

$$\rho = \frac{W_x^T C_{xy} W_y}{\sqrt{W_x^T C_{xx} W_x W_y^T C_{yy} W_y}} \tag{2}$$

The second criteria, canonical correlation coefficient (CCC), is the output from Canonical Correlation Analysis (CCA) that identifies maximum linear relationships between two multivariate sets of variables [2, 19]. As shown in eq (2), we select the ρ value that maximise the canonical correlation between x and y inputs with respect to the canonical variates W_x and W_y. The subscript x and y corresponds to response EEG and reference stimulus respectively where y is defined by Eq (3). In Eq (2), C_{xx}, C_{yy} are within-set covariance matrices and C_{xy} is between-set covariance matrix.

$$y = \begin{bmatrix} \sin(2\pi ft + \Phi) \\ \cos(2\pi ft + \Phi) \end{bmatrix} \tag{3}$$

where f is input stimulus frequency and ϕ is phase angle that is specified as 0, 45(□/4), 180 (□) and 225 (5□/4) degrees. After computing SAR and CCC of each EEG segment, we test normality of both features by applying Anderson-Darling test to choose either parametric or non-parametric tests according to data normality. For statistical analysis, we applied 1-way and 2-way ANOVA methods to determine which parameters and conditions exhibit influencing effects and interaction to SSVEP responses.

IV. Statistical Analysis And Results

First, we examined the spectral power amplitude of SSVEP responses of four stimulus frequencies. The similar amplitude responses (X-axis in Fig 5) but difference in amplitude response range (Y-axis in Fig 5) can be seen from spectral analysis across different experiment conditions. The Fig 5 shows mean spectral power amplitudes of SSVEP response at L_3 (30 degree view angle) stimulus position.

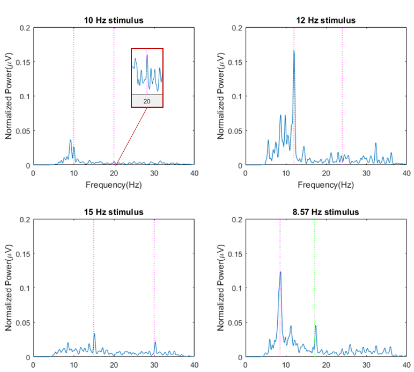

Fig. 5. Mean normalized spectral amplitudes of SSVEP reponses with four stimulus frequencies at L_3 stimulus position (first dotted vertical line is at fundamental frequency, second dotted line is at second haromic frequency)

Similar to [18], relatively high amplitude power exhibits around 9-10 Hz range in all frequencies though high distinct amplitude response to stimulus frequency can still be seen. But amplitude responses of 12Hz and 8.57Hz are more than 2 times higher than those of 10Hz and 15Hz as shown in Fig 5. Clear and distinct second harmonic responses were found on 8.57Hz and 15Hz compared with small harmonic peak for 10Hz and no second harmonic peak for 12Hz. The similar spectral responses of fundamental and harmonics can also be observed at other view angles.

A. *Statistical Analysis with CCC values*

The analysis of 1-way ANOVA with CCC values among spatial attention at specific view angle show no statistically significant difference among visual attention at each view angle as shown in Fig 6 (p-value at plot title). This suggests that different spatial attention oriented by subject has no effect on SSVEP response in single flickering stimulus eccentricity of 10 to 30 degrees view angle in left and right sides.

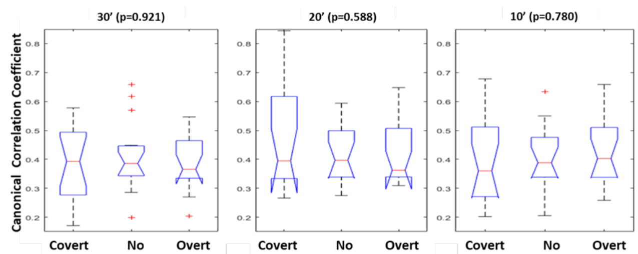

Fig. 6. Comparison of CCC values among three spatial attentions at specific view angles (with all stimulus frequencies)

The 2-way ANOVA analysis shows no difference between stimuli at left and right sides (p=0.84); meaning similar SSVEP responses (in CCC values) between left and right stimuli regardless of view angles. Another 1-way ANOVA analysis show no significant difference (p=0.57) among spatial attention in each frequency and view angle pair. This suggests the difference in view angles and visual attention has no influence on SSVEP responses with current stimulus frequencies.

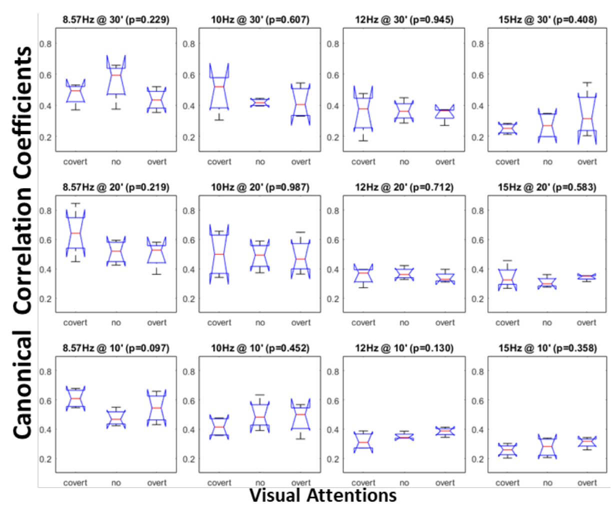

Fig. 7. Comparison of CCC values among visual attentions in a pair of stimulus frequencies and view angles (p-value at each plot title)

Although the differences in CCC values can be seen, there is not statistically significant among visual attention at different frequency-view angle pairs as shown in Fig 7. Unlike spectral amplitude difference in Fig 5, CCC values with 8.57Hz and 10Hz stimulus frequencies are in generally higher (though not statistically significant) than those with 12Hz and 15Hz stimulus frequencies. Further 2-way ANOVA results show there is no individual ($p=0.48$) and combined effect ($p=0.57$) of view angles and visual attention on CCC values. But CCC values depend on stimulus frequencies ($p<0.001$); implying SSVEP response is dependent on input stimulus frequency.

The length of EEG data segment in CCA analysis affects not only classification accuracy but also throughputs in SSVEP analysis using fovea vision with overt attention [2, 17]. In order to complete visual field test in a short duration, it is important to shorten the duration of flickering stimulus; resulting short data segment length in analysis. So we evaluated how different data segment length (from 1 to 4 sec) affect SSVEP responses (in CCC values) between fovea and peripheral vision as well as among different visual attentions and view angles.

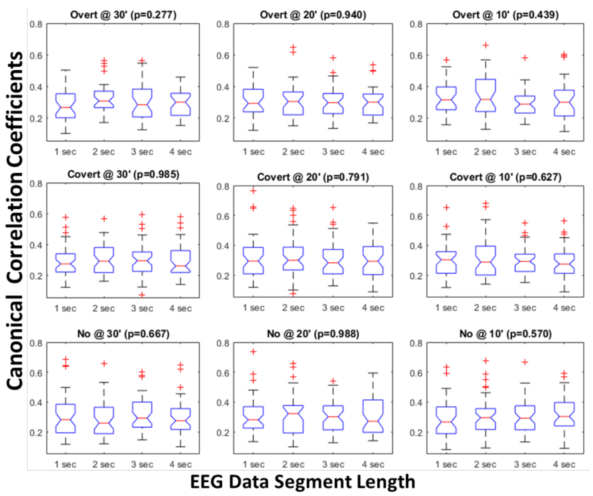

Fig. 8. Comparison of CCC values among different data segment length at peripheral view (with specific view angle and spatial attention pairs)

The Fig 8 shows there is no significant difference (p-value at each plot title) in CCC values among data segment length in peripheral vison under different attention and view angles. The 2-way ANOVA analysis result showed CCC values depend on stimulus frequency ($p=0.0003$) but do not depend on view angles and attention state ($p=0.41$). These results meant SSVEP responses in peripheral vision are not affected by segment length. So shorter data segment length can be used to achieve reliable SSVEP responses in peripheral vision.

B. Statistical Analysis *with SAR values*

In contrast to higher CCC values at 10Hz and 8.57Hz, SAR values of 12Hz and 15Hz are higher than those of 10Hz and 8.57Hz. The 1-way ANOVA analysis as shown in Fig. 9 show there is statistically significant difference ($p<0.001$) in SAR among different stimulus frequencies. Although SAR depends on stimulus frequency, SAR does not depend on view angles and attention states ($p=0.273$). From 2-way ANOVA, the stimulus frequency and attention state have combined effect on SAR values ($p=0.0001$). But there is no combined effect of stimulus frequency and view angles on SAR values ($p=0.131$). So stimulus frequency and attention are influencing experiment parameters on SSVEP responses in term of SAR.

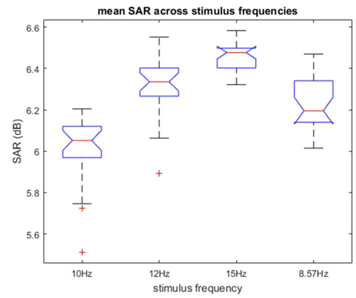

Fig. 9. Comparison of mean SAR across stimulus frequencies (All different visual attention and view angles)

We further examine which stimulus frequency is affected by visual attentions in terms of SAR. The 10Hz stimulus frequency show statistically significant difference in SAR values among visual attentions ($p=0.002$). But there is no significant difference in SAR among visual attention in other frequencies with p-values as shown in Fig 10. This means no influence of visual attentions to SSVEP responses in all stimulus frequencies expect 10Hz in terms of SAR.

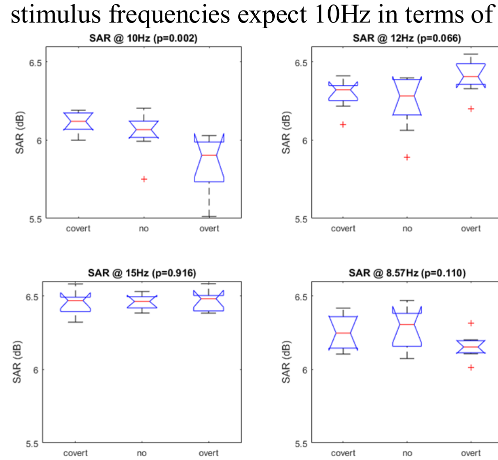

Fig. 10. Comparison of SAR among stimulus frequencies over three attentions

V. Discussion And Conclusion

Based on statistical analysis with SAR and CCC, SSVEP responses are only dependent on the stimulus frequency but independent on spatial attention and view angles. As data segment length has no influence on SSVEP responses, short flickering duration (1 sec) can be used to modulate reliable SSVEP responses. The independent between SSVEP responses and, data segment length, visual attention and view angles empowers SSVEP as suitable technique for visual field test. With specific stimulus frequency, we can able to characterise the relationship between SSVEP response and visual field loss. But, the view angles are only up to 30 degrees FoV with single stimulus displayed along horizontally instead of covering across the screen [6, 19]. It is required to use multiple stimuli flickering simultaneously to complete tests in a shortest possible time while covering effective FoV [5]. But, our test outcomes are based on data from three healthy subjects. So statistical test outcomes might have low statistical power resulting potentially high Type II errors. From these perspectives, we might need to further evaluate the effects of SSVEP responses with stimuli simultaneously flickered across wider FoV in different visual attentions using multiple subjects similar to actual visual field tests [4, 5]. We noticed that SSVEP responses in terms of SAR and CCC features are lower than those presented in [17, 19]. The factors resulting low SSVEP responses might be related to sub-optimal EEG data quality obtained from EEG amplifier with only two non-wet electrodes and stimulus flickering at 60 Hz monitor screen, etc. and experiment conditions compared with others [14, 17, 19]. Another important aspect is to evaluate stimulus frequency in mid and high frequencies beyond critical flickering fusion threshold to avoid visual discomfort [15, 17]. Such extensions might reveal how other frequency ranges beyond 8 – 15 Hz exhibit similar SSVEP responses or not under different view angles and visual attentions [17].

The current experiment only evaluated SSVEP responses in peripheral vision with different view angles horizontally subtended from center under three visual attentions using PSD [14] and CCA [19]. But view angles in study should subtend to wider FoV of 45 degrees or more covering far peripheral visual field [6]. It is also interesting to design and study the effect of flickering stimuli by circular or longitudinal motion instead of stationarity flickering as peripheral vision is more sensitive to motion [7]. Although our focus is in evaluating SSVEP for visual field assessment, outcomes from this study will be useful in designing gaze-independent BCI as reliable SSVEP detection can be obtained with covert visual attention in different view angles [12].

From statistical analysis, SSVEP responses between SAR and CCC showed differences although both are dependent on stimulus frequencies. The underlying difference is that SAR is computed from the spectral amplitude power features derived PSD analysis with time-domain signals where CCC is derived by applying multivariate analysis on time-domain signals. Also, the spectral amplitude power derived from PSD analysis has poor discriminative features compared with CCA [2]. As CCA can be used as spatial filtering to transform raw EEG into new feature spaces that can improve SNR and can provide better discrimination with linear relationship function [2].

From our knowledge, there is no study for evaluating how differences in visual attentions, view angles and stimulus frequencies affect SSVEP responses in peripheral vision. For automated FoV assessment using SSVEP, it is important to deliver objective assessment in short test duration, no active user participation and low test-retest variability [3, 5]. In this study, our goal is to examine SSVEP as measurement technique for objectively assessing visual field in Glaucoma patents. The current study evaluated how SSVEP responses exhibit in different view angles, attention states and frequencies with simple stimulus design. SSVEP responses from healthy subjects were analysed using spectral power ratio and canonical correlation coefficient features derived from the validated, segmented and pre-processed EEG data. We found out that selecting appropriate stimulus frequency is important for reliable SSVEP responses at specific view angle and visual attention. This is important step in visual field assessment using SSVEP by quantifying SSVEP responses, not influenced by subject's behaviors and test conditions, correlated only to potential visual field loss at specific FoV. Although the findings from current study are still in early stage with promising results, we are working towards further evaluation studies that can shed some lights on suitability of SSVEP as objective assessment for peripheral vision.

REFERENCES

[1] Blankertz, Benjamin et al. "The Berlin Brain-Computer Interface: Progress Beyond Communication and Control." Frontiers in Neuroscience, Vol. 10: 530, 2016.

[2] M. Nakanishi et al, "A high-speed brain speller using steady-state visual evoked potentials". Int. J. Neural Syst., Vol. 24(6), 2014.

[3] Norcia, A. M., et al. "The steady-state visual evoked potential in vision research: A review." J Vis, Vol. 15(6): 4, 2015.

[4] Hu, Cindy X. et al. "What Do Patients With Glaucoma See? Visual Symptoms Reported by Patients With Glaucoma." *The American Journal of the Medical Sciences, Vol.* 348(5): 403–409. *2014*.

[5] Nakanishi, M., et al. "Detecting glaucoma with a portable brain-computer interface for objective assessment of visual function loss." JAMA Ophthalmology, Vol. 135(6): 550-557, 2017.

[6] Hébert-Lalonde, N., et al. "A frequency-tagging electrophysiological method to identify central and peripheral visual field deficits." Documenta Ophthalmologica, Vol. 129(1): 17-26, 2014.

[7] Rosenholtz, R. "Capabilities and Limitations of Peripheral Vision." Annual Review of Vision Science, Vol. 2(1): 437-457, 2016.

[8] Kelly, S. P., et al. "Visual spatial attention control in an independent brain-computer interface." IEEE Transactions on Biomedical Engineering, Vol. 52(9): 1588-1596, 2005.

[9] M. Ordikhani-Seyedlar, et al, "SSVEP-modulation by covert and overt attention: Novel features for BCI in attention neuro-rehabilitation," 36th EMBC, pp. 5462-5465, 2014

[10] Kulke LV, Atkinson J and Braddick O, Neural Differences between Covert and Overt Attention Studied using EEG with Simultaneous Remote Eye Tracking. Front. Hum. Neurosci. Vol. 10:592, 2016.

[11] Ding, J., et al. "Attentional modulation of SSVEP power depends on the network tagged by the flicker frequency." Cerebral cortex, Vol. 16(7): 1016-1029, 2006.

[12] D Zhang et al, An independent brain–computer interface using covert non-spatial visual selective attention, J. Neural Eng. Vol. 7(1), 2010

[13] Müller, M. M., et al. "Sustained division of the attentional spotlight." Nature Vol. 424 (6946): 309 - 312, 2003.

[14] S. Walter et al, Effects of overt and covert attention on SSVEP, Neuroscience Letters, Vol. 519(1): 37– 41, 2012.

[15] Johansson, B. and P. Jakobsson. "Fourier analysis of steady-state visual evoked potentials in subjects with normal and defective stereo vision." Doc Ophthalmol, Vol. 101(3): 233-246, 2000.

[16] Gao, X. R., Xu, D. F., Cheng, M., and Gao, S. K. A BCI-based environmental controller for the motion-disabled. *IEEE Trans. Neural Syst. Rehabil. Eng.* Vol. 11(2): 137–140, 2003.

[17] F. C. Lin *et al.*, "SNR analysis of high-frequency steady-state visual evoked potentials from the foveal and extrafoveal regions of Human Retina," *Proc. IEEE EMBC*, San Diego, CA, pp. 1810-1814, 2012.

[18] Xie S, Liu C, Obermayer K, et al. Stimulator Selection in SSVEP-Based Spatial Selective Attention Study. Computational Intelligence and Neuroscience. 2016:6410718, 2016.

[19] Z. Nannan et al, "Detect visual field using eye tracking and steady-state visual evoked potential," Proc IEEE Int. Conf. on Systems, Man, and Cybernetics (SMC), Banff, AB, 2017, pp. 3125-3128, 2017.